Ecological aspects of new populations of the threatened Golden sun moth *Synemon plana* on the Victorian Volcanic Plains

Geoff Brown, Arn Tolsma and Ed McNabb

Arthur Rylah Institute for Environmental Research, Department of Sustainability and Environment,
123 Brown Street, Heidelberg, Victoria 3084. Email: geoff.brown@dse.vic.gov.au

Abstract

Targeted surveys for the threatened Golden sun moth *Synemon plana* (Lepidoptera: Castniidae) (GSM) were conducted across the Victorian Volcanic Plains in the summers of 2009 and 2010 in order to address the lack of information for this moth in this bioregion. We aimed to locate new populations and accumulate further ecological information for the moth. New populations were recorded at 46 sites overall, many of which were located in the west of the Victorian Volcanic Plains, presumably because of more intensive survey effort there. Survey returns differed between years, most likely as a consequence of different weather conditions. The GSM was generally located at sites dominated by native grasses, and was significantly positively correlated with wallaby grasses *Rytidosperma* spp. Both the habitat of GSM and the weather conditions under which the moth is active may not be as strictly defined as previously thought. *(The Victorian Naturalist* **129** (3), 2012, 77–85)

Keywords: grasslands, Lepidoptera, threatened invertebrate, survey protocol

Introduction

The Golden sun moth *Synemon plana* Walker, 1854 (Lepidoptera: Castniidae) (GSM) is a medium-sized (wingspan 31–34 mm) day-flying moth restricted to Victoria, the Australian Capital Territory and adjacent areas of southern New South Wales (Fig. 1) (Department of the Environment Water Heritage and the Arts 2009; O'Dwyer and Attiwill 2000).

The GSM was listed in December 2002 as Critically Endangered under the Commonwealth *Environment Protection and Biodiversity Conservation Act* 1999. The GSM is also listed as Critically Endangered in Victoria (http://www.dse.vic.gov.au/plants-and-animals/native-plants-and-animals) and Endangered in both New South Wales (http://www.threatenedspecies.environment.nsw.gov.au) and the Australian Capital Territory (http://www.tams.act.gov.au/play/pcl/conservation_and_ecological_communities). The GSM is also listed as a threatened species under the Victorian *Flora and Fauna Guarantee (FFG) Act* 1988 (Department of Sustainability and Environment 2008), and in an Action Statement prepared for it (Department of Sustainability and Environment 2004).

This moth inhabits grassy areas, including native grasslands and grassy woodlands as well as areas of introduced pasture grasses and weeds. An open tussock structure with sparse inter-tussock spaces or much bare ground is presumed to be an important attribute of a site supporting the species (Department of the Environment Water Heritage and the Arts 2009; Gilmore *et al.* 2008). Historically, this moth was thought to be confined to areas of native grassland and grassy woodland where the cover of wallaby grasses *Rytidosperma* spp. exceeds 40% (O'Dwyer and Attiwill 2000). However, recent surveys around Melbourne, including those reported here, revealed that non-native grasslands were also used by this species, including sites where the cover of wallaby grasses was much lower than 40% (Biosis Research Pty Ltd 2008; Brown and Tolsma 2010). In this paper, wallaby grasses are ascribed to the genus *Rytidosperma*, recently assembled from several genera, including *Austrodanthonia* (Linder *et al.* 2010).

The larvae of GSM are believed to spend two to three years underground and feed on the roots of native and some introduced grasses. The adult moths emerge usually from mid-October to early January, although this varies between years depending on climate and location (Department of the Environment Water Heritage and the Arts 2009). Adult moths do not have functional mouthparts and therefore are unable to feed. They live for just a few days after emergence (O'Dwyer and Attiwill 2000). The GSM exhibits a high degree of sexual dimorphism and the females are semi-flightless: they tend to remain on the ground, exposing their brightly-coloured hind wings to attract

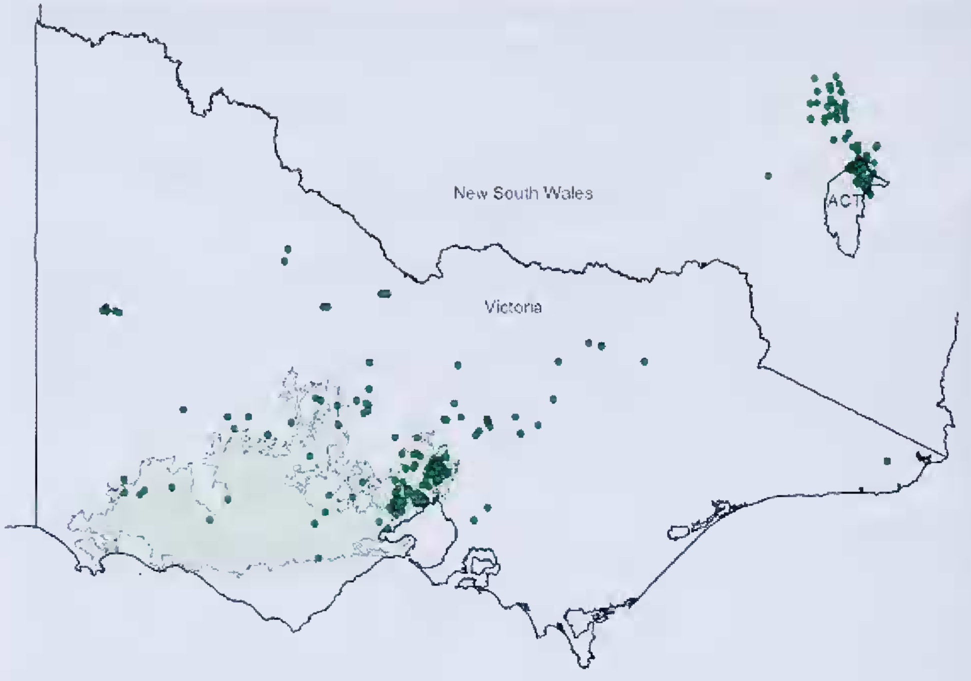

Fig. 1. Confirmed locations of the GSM in south-eastern Australia (Victorian Biodiversity Atlas, DSE, and Daniel Gilmore, Biosis Research Pty Ltd). Pale green shading = Victorian Volcanic Plains.

low-flying patrolling males (Department of Sustainability and Environment 2004; Department of the Environment Water Heritage and the Arts 2010).

Recent surveys around Melbourne have increased the number of known populations of this species, particularly to Melbourne's north and west (e.g. Biosis Research Pty Ltd 2008; Gilmore *et al.* 2008), yet little is known of its occurrence further west across the Victorian Volcanic Plains bioregion, south-western Victoria, which predictive modelling suggests will provide many areas of potentially suitable habitat (M White, pers. comm.). Records from the Victorian Biodiversity Atlas (Department of Sustainability and Environment) reveal that, prior to our surveys, 200 records existed for the GSM on the Victorian Volcanic Plains, most of which (91%) were located within 60 km of the Melbourne CBD, primarily as a result of surveys preceding urban development (e.g. Biosis Research Pty Ltd 2008) (Fig. 2).

Aim

The general aim of this project was to undertake on-ground surveys for the GSM across the Victorian Volcanic Plains during the 2009 and 2010 flight seasons to further determine the distribution of the species within this bioregion and refine our understanding of GSM habitat.

Methods

Study area

The Victorian Volcanic Plains bioregion covers 2.3 million ha (10.4% of Victoria) and is delimited by Portland (in the west), Craigieburn (east), Clunes (north) and Colac (south) (Fig. 2). It is characterised by extensive grasslands and grassy woodlands with many natural wetlands, a long history of agriculture (sheep, dairying, cattle grazing and mixed cropping on sown pasture) and small blocks of public land. The native vegetation of this bioregion is one of the most depleted in Victoria; it is highly fragmented and only 4.5% still has a cover of native vegetation; less than 1.2% remains in formal reserves (Taylor *et al.* 2003).

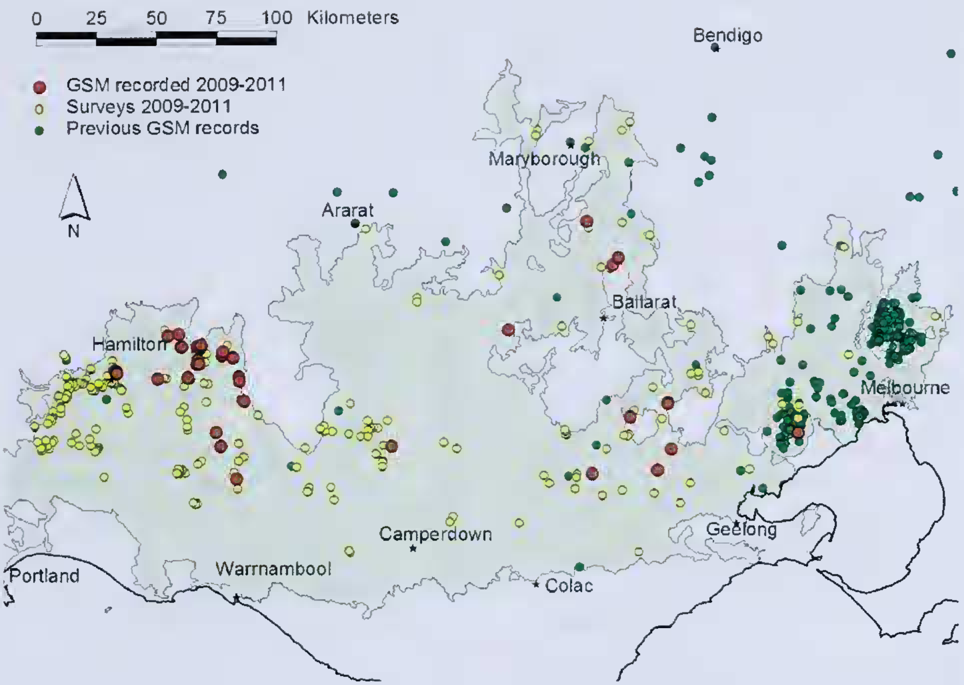

Fig. 2. Locations of GSM survey sites and records in the Victorian Volcanic Plains (pale green shading), western Victoria.

Site selection

Potential survey areas across all land tenures were identified by combining a distribution model for GSM (based on all known sightings) with a probability model for the distribution of native grassland/native pasture (circa 2005) (M White, pers. comm.), its putative primary habitat. In this way the broad geographical (and ecological) extent of potential habitat was incorporated into the survey design; those localities with the greatest likelihood of providing GSM habitat were preferentially targeted for survey.

To further refine the survey focus, all public land in the Victorian Volcanic Plains, including conservation reserves and roadside reserves, was identified and mapped, and satellite and other data used to identify all those areas of public land that might be suitable for GSM survey (cleared or grassland rather than forest and not a water-body, coastal reserve, military land etc.). Potentially suitable private properties, identified from various sources, including responses to advertisements in local and regional newspapers, were surveyed only if permission was granted. Thus, in the moth flying seasons of 2009 (November-December 2009) and 2010 (November 2010-February 2011), a series of sites representing different land tenures across the Victorian Volcanic Plains was surveyed for GSM activity.

Survey protocol

Problems associated with the survey of the GSM are well documented (Gibson and New 2007) and, *inter alia*, include ephemerality of the adult stage of the moth, crypsis of the female moth, the influence of weather on moth activity and hence detectability, a largely unpredictable flight season, and the assumption that when moths are flying in one locality they are likely to be flying in another locality within a reasonable distance.

With limited resources available, a higher priority was given to locating new populations across a broad area than confirming the absence of the moth on a particular site by repeated visits, as the accepted protocol for assessing the presence and abundance of the GSM dictates (Department of the Environment Water Heritage and the Arts 2008; 2009; Gibson and New 2007). No estimate of total population size was required, just confirmation of occurrence and a count of individuals observed at the time. Hence, single visits to a large number of sites was considered appropriate.

The methods for surveying the GSM were based on those documented elsewhere (Department of the Environment Water Heritage and the Arts 2008; 2009; Gibson and New 2007). Surveys were conducted only during appropriate weather conditions, at a suitable time of day, by experienced observers, and undertaken only when moths were known to be flying at known locations in the region. Surveys were conducted when conditions were considered suitable for male flight: warm, relatively still, clear, sunny days, >20°C (and preferably >30°C), between 10 am and 3 pm. Weather details were routinely recorded for all surveys, as was survey effort (duration, distance). Survey transects were configured so as to cover the maximum practical amount of a study site. For instance, multiple parallel transects, 20 m wide, were employed in a paddock, while roadside transects often comprised a single extended transect on each side of the road. When GSM were found, the locality was recorded on a hand-held GPS unit and habitat details documented; these included a visual assessment of the dominant ground cover and proportion of bare ground. At the completion of the surveys, the occurrence of GSM was correlated with the cover of wallaby grasses using simple linear regression.

Results

GSM surveys were conducted from 18 November to 30 December, 2009, and from 10 November, 2010 to 2 February, 2011. In total, 307 sites were surveyed, 166 during summer 2009 and 141 during summer 2010 (Table 1). Surveys were undertaken mostly on public land (38.1%) and along roadsides (31.2%), primarily because suitable private properties were difficult to locate and access. The 2010 surveys were more evenly dispersed than those of 2009, with a greater proportion of surveys conducted in the northern and eastern portions of the bioregion.

In 2009, the GSM was observed at 26 sites, mostly in the west around Hamilton, primarily due to greater survey effort in that area. Sites

Table 1. Golden Sun moth sightings across the Victorian Volcanic Plains by land tenure, summer 2009 and 2010.

	Summer 2009			Summer 2010			Total		
	Total sites	Sites with GSM	% sites with GSM	Total sites	Sites with GSM	% sites with GSM	Total sites	Sites with GSM	%sites with GSM
Private land	35	6	17.1	48	8	16.7	83	14	16.9
Public land	44	7	15.9	73	8	11.0	117	15	12.8
Roadside	87	13	14.9	9	2	22.2	96	15	15.6
Tenure unknown	0	0	0	11	2	18.2	11	2	18.2
Total	166	26	15.7	141	20	14.2	307	46	15.0

with GSM were generally along roadsides and on public land, commensurate with the larger number of sites surveyed in these land tenures. A total of 191 GSM was observed during the 2009 surveys, of which 177 were males and 14 were females. The GSM was first recorded on December 2, and the last sighting was on December 30, 2009. Fewer sites were surveyed in summer 2010 due to a lack of suitable weather. These surveys yielded a total of 65 GSM, 55 males and 10 females, from 20 sites. The first GSM was recorded on November 23, 2010, and the last on January 20, 2011. Moth activity varied substantially between seasons and sites; moth numbers per site varied between 1 and 40 (Table 2).

Weather conditions proved to be an issue during the 2010 survey season — few days were suitable for surveys. For example, at Hamilton Airport the temperature exceeded 30°C on only nine days during summer, while some rain fell on 38 days (http://www.bom.gov.au/). The wetter, cooler season (compared to the 2009 season) was likely to have affected GSM activity, with numbers sighted being particularly low; the highest number recorded during a survey was eight. In contrast, six surveys in 2009 each detected 10 or more individuals. Most GSM were detected when temperatures were 20 to 35°C, cloud cover was 0-25% and winds were light. However, our results show that GSM could occasionally be observed under conditions presumed less optimal, with five GSM detected at one site when the temperature was only 19°C and wind was gusting to 25 km/h.

A visual assessment was made of the dominant ground cover taxa at each GSM site. It was not always possible to identify grass taxa confidently, particularly when sites were mown or heavily grazed; in such cases, the generic term 'introduced grasses' was assigned. It is possible that native grass species were underestimated in these instances.

The ground vegetation of survey sites where GSM were located was variously dominated by native taxa, primarily grasses: wallaby grasses, spear grasses *Austrostipa* spp., Kangaroo Grass *Themeda triandra* and Weeping Grass *Microlaena stipoides* (Table 2). This is not surprising, given that prospective study sites were identified *a priori* by mapping native grassland/pasture. Even so, 19 of 46 (41%) sites revealed at least 10% ground cover of introduced taxa. Several sites were dominated by high cover of Brown-top Bent *Agrostis capillaris*, Couch Grass *Cynodon dactylon*, or Perennial Ryegrass *Lolium perenne* (Table 2).

GSM were found mostly at sites with ≥ 10% cover of wallaby grasses (Table 2). The contribution by wallaby grasses varied substantially across GSM sites, from none recorded to 80% cover. Where wallaby grasses were recorded they had a mean cover of 30.5% (±3.5 s.e.). Wallaby grasses were not always present at GSM sites, but there was nonetheless a positive relationship between the cover of wallaby grasses and the number of GSM sighted (simple linear regression, $P = 0.012$) (Fig. 3). This suggests that wallaby grasses may indeed be useful to the moths (or an indicator of good habitat), even though these plants appear not to be essential for them. The proportion of bare ground on GSM sites fell in the range 0-60%, with a mean of 16.4% (±2.2 s.e.).

Discussion

The 2009 and 2010 summer surveys of the Victorian Volcanic Plains confirmed the presence of the GSM at new locations, mostly in the west around Hamilton and Dunkeld, and elsewhere, including north of Ballarat and around Meredith. These new records are likely to reflect increased survey effort rather than range extensions — to our knowledge, no regional-scale surveys have been conducted for the GSM in western Victoria.

While it was not the objective of this study to evaluate GSM population sizes — we simply wanted to confirm the presence of the moth — no comparative assessment of populations was possible because study sites differed in size, the effort per site varied and weather conditions differed between surveys (despite attempts to survey under optimal conditions).

Indeed, the study had several limitations, including detectability and observer bias, which we attempted to address in our approach to the survey. That is, surveys were conducted only during suitable weather (although this rule was slightly relaxed in the 2010 season when it became apparent that the number of suitable days was likely to be few), observers were ex-

Table 2. Golden Sun moth sightings by dominant ground vegetation taxa (as % cover) and proportion of bare ground, where recorded, summer 2009 and 2010. * = introduced.

Year	Number of GSM	Dominant taxon 1	%	Dominant taxon 2	%	Dominant taxon 3	%	Bare ground (%)
2009	40	Introduced grasses*	60					40
2009	23	*Rytidosperma* spp.	80	Native grasses	15			1
2009	16	*Themeda triandra*	40	*Rytidosperma* spp.	40	*Austrostipa* spp.	5	5
2009	15	*Agrostis capillaris**	60	*Microlaena stipoides*	10	*Austrostipa* spp.	10	20
2009	12	Native grasses	80	Introduced grasses*	10			10
2009	10	*Rytidosperma* spp.	70	*Wahlenbergia* spp.	5	Flat weeds*	5	10
2009	9	*Rytidosperma* spp.	50	*Themeda triandra*	20	*Bothriochloa macra*	10	5
2010	8	*Rytidosperma* spp.	55	*Paspalum* spp.*	10	*Arctotheca calendula**	5	20
2009	7	*Rytidosperma* spp.	25	Native grasses	25	Introduced grasses*	10	40
2009	6	*Rytidosperma* spp.	45	*Austrostipa* spp.	5	*Elymus scaber*	3	35
2009	6	*Rytidosperma* spp.	40	*Themeda triandra*	30	*Austrostipa* spp.	5	15
2009	6	*Austrostipa* spp.	70	*Rytidosperma* spp.	10	*Paspalum* spp.*	10	5
2009	6	*Microlaena stipoides*	40	*Rytidosperma* spp.	30			10
2009	6	*Themeda triandra*	40	*Rytidosperma* spp.	15	*Lomandra* spp.	10	5
2010	6	*Rytidosperma* spp.	30	*Microlaena stipoides*	30	*Holcus lanatus**	30	2
2010	6	*Rytidosperma* spp.	10	*Microlaena stipoides*	10	*Cynodon dactylon**	10	50
2010	6	*Rytidosperma* spp.	60	*Themeda triandra*	20	*Elymus scaber*	4	10
2009	5	*Rytidosperma* spp.	10	*Themeda triandra*	10	*Austrostipa* spp.	10	50
2010	5	*Rytidosperma* spp.	20	*Cynodon dactylon**	20	*Themeda triandra*	10	15
2010	5	*Cynodon dactylon**	70	*Rytidosperma* spp.	10	Moss	5	5
2010	5	*Microlaena stipoides*	60	*Eucalyptus camaldulensis*	15	*Rytidosperma* spp.	10	5
2009	4	*Agrostis capillaris**	60	*Anthoxanthum odoratum**	10	*Rytidosperma* spp.	5	5
2009	4	*Rytidosperma* spp.	40	*Themeda triandra*	30	*Austrostipa* spp.	10	15
2009	4	Native grasses	35	Introduced grasses*	7			30
2009	3	*Rytidosperma* spp.	40	*Phalaris aquatica**	20	*Themeda triandra*	20	5
2010	3	*Rytidosperma* spp.	50	*Hypochoeris radicata**	10	*Austrostipa* spp.	5	10
2010	3	*Rytidosperma* spp.	60	*Agrostis capillaris**	12	*Elymus scaber*	10	10
2010	3	*Austrostipa* spp.	40	*Rytidosperma* spp.	5			20

Table 2. (Continued)

Year	Number of GSM	Dominant taxon 1	%	Dominant taxon 2	%	Dominant taxon 3	%	Bare ground (%)
2010	3	*Themeda triandra*	25	*Austrostipa* spp.	25			5
2010	3	*Themeda triandra*	65	*Austrostipa* spp.	12	*Rytidosperma* spp.	10	2
2009	2	*Rytidosperma* spp.	25	Native grasses	40	*Agrostis* spp.*	10	15
2010	2	*Rytidosperma* spp.	40	*Austrostipa* spp.	10	*Poa* spp.	5	20
2009	1	*Rytidosperma* spp.	15	*Austrostipa* spp.	10	*Microlaena stipoides*	5	50
2009	1	*Rytidosperma* spp.	60	*Themeda triandra*	5	*Austrostipa* spp.	5	20
2009	1	*Rytidosperma* spp.	60					20
2009	1	*Lolium perenne**	90	*Rytidosperma* spp.	5	*Avena* spp.*	5	0
2009	1	Introduced grasses*	30	*Rytidosperma* spp.	10	*Austrostipa* spp.	10	10
2009	1	*Themeda triandra*	10	*Rytidosperma* spp.	5	*Microlaena stipoides*	5	60
2009	1	*Themeda triandra*	90					0
2010	1	*Anthoxanthum odoratum*	25	*Themeda triandra*	25	*Poa* spp.	10	5
2010	1	*Rytidosperma* spp.	50	*Arctotheca calendula**	10	Introduced grasses*.		10
2010	1	*Rytidosperma* spp.	25	*Microlaena stipoides*	10	*Themeda triandra*	10	20
2010	1	*Austrostipa* spp.	40	*Rytidosperma* spp.	20	Mixed aquatic vegetation	20	7
2010	1	Introduced grasses*	50	*Themeda triandra*	5			
2010	1	*Themeda triandra*	55	*Rytidosperma* spp.	10	*Microlaena stipoides*	5	20
2010	1	*Themeda triandra*	25	*Rytidosperma* spp.	15	*Bothriochloa macra*	15	20

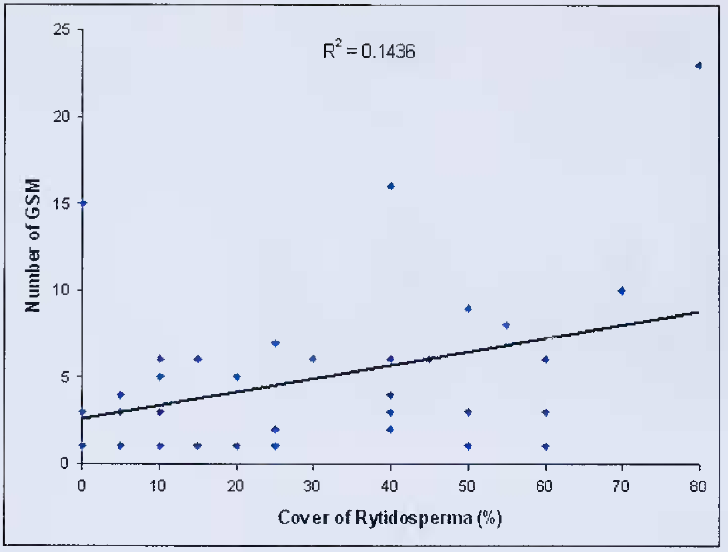

Fig. 3. Relationship between GSM sightings and the estimated % cover of wallaby grasses *Rytidosperma* spp., 2009-2011 surveys.

perienced and familiar with GSM behaviour, sufficient time was devoted to survey on each prospective site, and surveys were conducted only when moths were known to be flying at strategic reference localities. A single visit to each prospective site is the major limitation of this study, especially given unpredictable emergence times and activity levels of the moth; consequently, there are likely to be false absences in the data. Gilmore *et al.* (2008) believe that the occurrence of the GSM at a site can be determined by a maximum of two site visits, provided certain survey conditions are adhered to, centred on timing, weather conditions and survey effort. This contrasts with a widely-adopted peri-urban survey protocol, which advocates up to four ever-intensive searches at sites, while noting that this approach is designed to substantiate the absence of GSM rather than confirm presence (Department of the Environment Water Heritage and the Arts 2008).

The 2010 surveys for GSM were undertaken when weather conditions were assumed *a priori* to be suitable (sunny, warm to hot, low cloud cover and light wind), limiting analyses of the relationship between GSM sightings and weather conditions. Nonetheless, our data show that GSM could be occasionally observed under conditions presumed less optimal. Moths were observed (sometimes in high numbers) at four sites when cloud cover was 25-50%, and one was found at a site when cloud cover was 50-75%. Six moths were found at one site in light-moderate winds (average wind speed 4.4 km/h, but gusting to 27.6 km/h) when the temperature was 39°C, and moths were observed flying at two sites in mid-morning when the temperature had not yet reached 20°C and cloud cover was low.

Historically, the GSM was thought to be confined to areas of native grassland and grassy woodland with a cover of wallaby grasses of more than 40% but with an open tussock structure that allowed for bare spaces (O'Dwyer and Attiwill 2000). Recent surveys around Melbourne indicated that non-native grasslands were also used by this species, including sites where the cover of wallaby grasses was much lower than 40%; these sites were often heavily infested with Chilean needle-grass *Nassella neesiana* and other exotic grass species (Biosis Research Pty Ltd 2008; Gilmore *et al.* 2008). We found no infestations of Chilean needle-grass on sites supporting GSM during our study, although it is now well established throughout Victoria and common in the eastern third of the Victorian Volcanic Plains, and it is known to favour more fertile soils, particularly volcanic soils (http://www.weeds.org.au/).

Our data partially support both findings: the presence of wallaby grasses was important, yet eight of the 46 GSM sites were dominated by introduced grasses, including Brown-top Bent (Table 2). The greatest number of GSM observed (30 males and 10 females) was at the Parklands Golf Club, Hamilton, but the observer was unable to identify the grass species on the edge of the closely-mown fairway. Native grasses dominated the nearby 'rough', and given that there is a high cover of bare ground (40%), the fairway grass is likely to be an opportunistic mix of introduced and native grasses. It is possible that GSM were using the fairway only for searching after breeding in the 'rough'. The value of golf courses for insect conservation has been acknowledged elsewhere (New 2005).

Some introduced grass species may have a suitable tussock form that allows female GSM to oviposit and larvae to feed. However, it remains to be determined whether exotic tussocks are suitable for supporting sustainable, long-term populations, or represent an inferior last resort.

Conclusion

Our study has improved substantially the knowledge of the distribution and habitat of the GSM on the Victorian Volcanic Plains. The GSM is likely to be more widespread than current records suggest, as evidenced hy the plethora of recent discoveries in grasslands on the periphery of Melbourne as a consequence of intensive surveys. The fact that the moth is regularly found in locations dominated by introduced grasses — not the focus of this study — also suggests a broader distribution. We advocate further surveys to clarify the moth's distribution and conservation status, and believe that studies that incorporate the influences on detectability of weather and survey approach (including technique and effort) will also be useful.

Acknowledgements

The authors would like to acknowledge the contributions that the following individuals and agencies made to the completion of this paper: Adam Muir, James Todd, Kim Lowe and Richard Boekel (Biodiversity and Ecosystem Services, DSE, East Melbourne) for project oversight; Richard Loyn and David Cheal (both ARI) for project administration; Chelsey Langley (Corangamite Catchment Management Authority) for information; Brian Bainbridge (Merri Creek Management Committee) and Daniel Gilmore (Biosis Research Pty Ltd) for GSM locality and flying information; land-holders who kindly allowed access to their properties. Particular thanks are due to Lauren Eddy (Plume Ecology Pty Ltd), Liz Fenton, Neil Hives (IPM Technologies Pty Ltd), and Jane Woodburn, for enthusiastically conducting field surveys, and to Matt White (ARI) for modelling GSM distribution. This paper was improved by the comments of Fiona Coates (ARI). This project was funded by the Victorian Department of Sustainability and Environment.

References

Biosis Research Pty Ltd (2008) Targeted survey of the Golden Sun moth in the Melbourne Area. Final Report. Provided to the Department of the Environment and Heritage on behalf of FKP Commercial Developments Pty Ltd. Biosis Research Pty Ltd, Port Melbourne.

Brown G and Tolsma A (2010) A survey for the Golden Sun moth *Synemon plana* on the Victorian Volcanic Plains, 2009. Unpublished report to the Department of Sustainability and Environment. Arthur Rylah Institute for Environmental Research, Heidelberg, Victoria.

Department of Sustainability and Environment (2004) Action Statement No. 106. Golden Sun moth *Synemon plana*. (DSE: East Melbourne, Victoria)

Department of Sustainability and Environment (2008) Flora and Fauna Guarantee Act 1988. Threatened List. (DSE: East Melbourne, Victoria)

Department of the Environment Water Heritage and the Arts (2008) EPBC Act Policy Statement 3.12. Significant impact guidelines for the critically endangered Golden Sun moth (*Synemon plana*). DEWHA, Barton, ACT.

Department of the Environment Water Heritage and the Arts (2009) Background Paper to the EPBC Act Policy Statement 3.12 – Nationally Threatened Species and Ecological Communities. Significant impact guidelines for the critically endangered Golden Sun moth (*Synemon plana*). DEWHA, Barton, ACT.

Department of the Environment Water Heritage and the Arts (2010) *Synemon plana* in Species Profile and Threats Database. (DEWHA: Canberra)

Gibson L and New TR (2007) Problems in studying populations of the golden sun moth, *Synemon plana* (Lepidoptera: Castniidae), in south eastern Australia *Journal of Insect Conservation* **11**, 309–313.

Gilmore D, Koehler S, O'Dwyer C and Moore W (2008) Golden Sun moth *Synemon plana* (Lepidoptera: Castniidae): results of a broad survey of populations around Melbourne. *The Victorian Naturalist* **125**, 39–46.

Linder HP, Baeza M, Barker NP, Galley C, Humphreys AM, Lloyd KM, Orlovich DA, Pirie MD, Simon BK, Walsh N and Verboom GA (2010) A generic classification of the danthonioideae (Poaceae). Annals of the Missouri Botanical Garden **97**, 306–364.

New TR (2005) Recreation and reserves: Values of golf courses for insect conservation. *Journal of Insect Conservation* **9**, 1–2.

O'Dwyer C and Attiwill PM (2000) Restoration of a native grassland as habitat for the Golden Sun moth *Synemon plana* Walker (Lepidoptera; Castniidae) at Mount Piper, Australia. *Restoration Ecology* **8**, 170–174.

Taylor R, Wierzbowski P, Lowe KW, Ross J, Moorrees A and Ahern L (2003) Biodiversity Action Planning. Strategic overview for the Victorian Volcanic Plain bioregion. Department of Sustainability and Environment, East Melbourne.

Received 22 September 2011; accepted 8 March 2012